PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant' s or agent's f ile reference 25621	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/IL03/00291	International filing date *(day/month/year)* 07 April 2003 (07.04.2003)	Priority date *(day/month/year)* 15 April 2002 (15.04.2002)
International Patent Classification (IPC) or national classification and IPC IPC(7): G02B 27/26 and US Cl.: 359/465		
Applicant WEISSMAN, YITZHAK		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of report with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☒ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
30 October 2003 (30.10.2003)	06 December 2004 (06.12.2004)
Name and mailing address of the IPEA/US Mail Stop PCT, Attn: IPEA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703) 305-3230	Authorized officer Drew Dunn Telephone No. (571) 272-2312

Form PCT/IPEA/409 (cover sheet)(July 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL03/00291

I. Basis of the report

1. With regard to the **elements** of the international application:*

☐ the international application as originally filed.

☒ the description:
pages 1-2, 6-12, 15 as originally filed
pages NONE, filed with the demand
pages 3-5,13 and 14, filed with the letter of 02 June 2004 (02.06.2004)

☒ the claims:
pages NONE, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages 16-18, filed with the letter of 02 June 2004 (02.06.2004)

☒ the drawings:
pages 1-16, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of

☐ the sequence listing part of the description:
pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language ____ which is:

☐ the language of a translation furnished for the purposes of international search (under Rule23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination(under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in printed form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages NONE

☐ the claims, Nos. NONE

☐ the drawings, sheets/~~fig~~ NONE

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

*** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONAL PRELIMI[redacted]Y EXAMINATION REPORT

International ap[redacted]ion No.
PCT/IL03/002[redacted]

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. STATEMENT

Novelty (N)	Claims 1-15	YES
	Claims NONE	NO
Inventive Step (IS)	Claims 2-7, 10-15	YES
	Claims 1, 8, 9	NO
Industrial Applicability (IA)	Claims 1-15	YES
	Claims NONE	NO

2. CITATIONS AND EXPLANATIONS

Claims 1 and 9 lack an inventive step under PCT Article 33(3) as being obvious over Divelbliss et al (US 2001/0028416). Divelbliss et al teach in figs. 10 and 12 a stereoscopic display apparatus comprising two LCD projectors that each output a set of color components (red, blue, and green) of stereoscopic images such that one color (green) component has a polarization state orthogonal to the other color components (red and blue), a polarization preserving screen, and optical filter system using exclusively optical retarders to manipulate the polarization states for polarizing the output beams of the two projectors into mutually orthogonal polarization states, and a stacking means for combining the sets onto the screen for viewing with polarized filters. Divelbliss et al does not explicitly state in this embodiment the use of polarizing clean-up filters for increasing the polarization ratio of the output beam. However in the embodiment shown in fig. 9, Divelbliss et al teaches using polarizing clean-up filters (112 and 114) for increasing the polarization ratio of the output beam (page 3, section [0034]). It would have been obvious to one of ordinary skill in the art at the time of the invention to use polarizing clean-up filters in this embodiment of Divelbliss et al to remove stray light and increase the polarization ratio of the output beam.

Claim 8 lacks an inventive step under PCT Article 33(3) as being obvious over Divelbliss et al in view of Currin et al (US 5,187,754). Divelbliss et al do not teach stacking the color sets by image warping. Currin et al teach the use of image warping to stack color sets. It would have been obvious to one of ordinary skill in the art at the time of the invention to use the image warping of Currin et al to stack the color sets of Divelbliss et al in order to reduce the number of components.

Claims 2-7 and 10-15 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest a polarization rectifier which transforms a plurality color components into the same polarization states at output by exclusively using optical retarders.

Claims 1-15 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL03/00291

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

The description is objected to as containing the following defect(s) under PCT Rule 66.2(a)(iii) in the form or contents thereof: On amended page 3, line 14 " stereoscopic display apparatus comprising:" is repeated.

reflective LCD microdisplays were described in Atarashi et al., U.S. Patent 5,172,254 and Colucci et al., U.S. Patent 6,231,189, respectively. Both utilize six LCD microdisplays, two for each color. Such projectors could be used for stereoscopic display, as each can accept two full-color images. The present invention focuses on using available off-the-shelf projectors or projection engines to avoid the high cost involved in development of new designs such as those described in the patents cited above.

OBJECTS AND BRIEF SUMMARY OF THE INVENTION

One object of the present invention is to provide stereoscopic display apparatus having advantages in the above respects. A more particular object of the present invention is to provide stereoscopic display apparatus which is optically efficient and which exhibits low cross talk between the left and right images.

According to a broad aspect of the present invention, there is provided stereoscopic display apparatus comprising: stereoscopic display apparatus comprising: two projectors having inputs connectable to a source of digital data representing the color components sets of two stereoscopic images, each of said projectors having an output outputting an optical beam having a set of color components in which at least one color component of the set is of an orthogonal polarization state with respect to the other color components of the set; a polarization preserving screen; an optical filter system using exclusively optical retarders to manipulate said polarization states for polarizing the output beams of the two projectors into desired mutually orthogonal polarization states; polarizing clean-up filters for increasing the polarization ratio of the output beams; and stacking means for stacking said two color sets onto said polarization preserving screen such as to enable stereoscopic viewing of the two color sets via orthogonally polarized filters.

Preferably, the optical filter system includes, for each projector, a polarization rectifier which transforms a plurality of color components in different polarization states at the input into the same polarization state at the output by using

exclusively the optical retarders for polarization manipulation. Two embodiments of polarization rectifiers are described. In one embodiment, the polarization rectifier includes a stack of optical retarders which align the polarizations of all color components. In second embodiment, the polarization rectifier includes: a splitter which separates the color components into two optical paths, a polarization transformer in at least one optical path which utilizes an optical retarder to transform the respective color component to another polarization state in such manner that mutually orthogonal polarization states are transformed to polarization states that are also mutually orthogonal; and a combiner which combines the two optical paths for stacking onto the polarization preserving screen.

The several embodiments of the invention, described below for purposes of example, differ considerably in many respects. They however share one common feature: all transformations of the main polarization states are done exclusively with optical retarders. This feature is fundamental to the present invention, as it allows the high optical efficiency.

According to another aspect of the invention, there is provided stereoscopic display apparatus comprising: two projection engines having inputs connectable to a source of digital data representing the color components sets of two stereoscopic images, each of the projection engines having an output outputting an optical beam having a set of color components in which at least one color component of the set is of an orthogonal polarization state with respect to the other color components of the set; a polarization preserving screen; a polarization rectifier for each projector effective to manipulate the polarization states exclusively by optical retarders, and to transform the beams outputted by the projection engines to beams in which all color components have the same polarization state in such a manner than the two transformed beams have mutually orthogonal polarizations; a polarization beam splitter for combining the transformed beams into one co-axial beam; and a projection lens for imaging the stereoscopic images on the screen.

As indicated earlier, the invention is particularly useful, and is therefore described below, with respect to LCD projectors outputting the red and blue color components in one polarization state, and the green color components in an orthogonal polarization state.

As will be described more particularly below, the foregoing features of the invention enable the construction of various types of stereoscopic display apparatus which are optically efficient and which exhibit low cross-talk between the left and right images.

Further features and advantages of the invention will be apparent from the description below.

from one or more pleochroic polarizers will be referred to as a "pleochroic clean-up filter".

Normally, the green color component in projectors has much higher intensity than the other two color components. In addition, the human eye response to the green color is higher than to the other colors. The combination of these facts makes the green color dominant in projected images. Therefore, cleaning the green color only may be sufficient in many applications. Using only one pleochroic polarizer to clean up the beam reduces cost and losses.

Filters Including Two Polarization Rectifiers

A polarization rectifier is an optical device that accepts two or more color components in different polarization states, and produces an output composed of all input components identically polarized. A block diagram of a polarization rectifier for a projector beam is shown in Fig. 11.

A block diagram of two polarization rectifiers filter is shown in Fig. 12. The two images sources are coupled directly to the projectors. A different polarization rectifier processes the output of each projector. The polarization rectifier of projector 1 transforms both the α and the β polarization states to another polarization state γ, and the polarization rectifier of projector 2 transforms both the α and the β polarization states to yet another polarization state δ, in such a manner that γ and δ are mutually orthogonal. The output beams are optionally cleaned up by regular polarizers. It is seen that the correct viewing conditions are created by disposing a γ polarization filter in front of eye no. 1, and a δ polarization filter in front of eye no. 2.

A possible embodiment of a polarization rectifier is shown in Fig. 13. In this embodiment it is assumed that the input polarization states α and β are linear, and that so is the output polarization state γ too.

A green-reflecting dichroic mirror splits the polarization states of the input beam. This mirror has the property that it reflects the green light, and transmits the red and the blue light. A half-wavelength retarder rotates each one of the separated polarization states so that both acquire the same polarization state γ. The two color

components, being now identically polarized are recombined by a red and blue reflecting dichroic mirror. The resultant output beam is made up of all three components polarized in state γ. The direction of state γ can be controlled by the orientations of the half-wavelength retarders.

Readers familiar with related optical techniques will recognize that a polarization beam splitter can replace the green-reflecting dichroic mirror at the input of the polarization rectifier. Also, when general polarization transformers are used instead of the half-wavelength retarders, an arbitrary output polarization state γ can be achieved.

Another device that can serve as a polarization rectifier for an LCD projector is a special stack of optical retarders as described, for example, by Sharp, U.S. Patent 6,310,673. Sharp teaches, among other things, how to make a filter that will rotate the green color polarization direction by 90°, while keeping intact the polarization plane of the other color components. Such a filter has an axis, which has to be aligned with the red and blue colors polarization direction in order to achieve the desired effect. When such a filter is mounted in the proper orientation to receive a cross-polarized LCD beam, all colors will emerge polarized in the same direction. Such green rotating filters are manufactured by ColorLink (Boulder, Colorado) under the commercial name ColorSelect™

The ColorSelect™ filter alone cannot produce a general linear output polarization state, like the filter shown in Fig. 13. A polarization rectifier with an arbitrary linear output polarization state can be created by combining a ColorSelect™ filter with a polarization transformer, as shown in Fig. 14.

Fig. 15 shows a compact polarization rectifier, which incorporates a clean-up filter. It is made of three layers: a green-rotating ColorSelect™ filter, a half-wavelength retarder, and a linear polarizer. The function of two such devices that can be used for a two polarization rectifiers filter is illustrated in Fig. 16. Fig. 16 (A) shows the original beams; Fig. 16 (B) shows the beams after the ColorSelect™ filter; and Fig. 16 (C) shows the beams after the half-wavelength retarder. The orientations of the three layers in both devices is shown in Fig. 17.

WHAT IS CLAIMED IS:

1. Stereoscopic display apparatus comprising:

two projectors having inputs connectable to a source of digital data representing the color components sets of two stereoscopic images, each of said projectors having an output outputting an optical beam having a set of color components in which at least one color component of the set is of an orthogonal polarization state with respect to the other color components of the set;

a polarization preserving screen;

an optical filter system using exclusively optical retarders to manipulate said polarization states for polarizing the output beams of the two projectors into desired mutually orthogonal polarization states;

polarizing clean-up filters for increasing the polarization ratio of the output beams;

and stacking means for stacking said two color sets onto said polarization preserving screen such as to enable stereoscopic viewing of the two color sets via orthogonally polarized filters.

2. The apparatus according to Claim 1, wherein said optical filter system includes, for each projector, a polarization rectifier which transforms a plurality of color components in different polarization states at the input into the same polarization state at the output by using exclusively said optical retarders for polarization manipulation.

3. The apparatus according to Claim 2, wherein each polarization rectifier includes: a splitter which separates the color components into two optical paths, a polarization transformer in at least one optical path which utilizes a said optical retarder to transform the respective color component to another polarization state in such manner that mutually orthogonal polarization states are transformed to polarization states that are also mutually orthogonal; and a combiner which combines the two optical paths for stacking onto said polarization preserving screen.

4. The apparatus according to Claim 3, wherein said splitter is a dichroic mirror.

5. The apparatus according to Claim 3, wherein said splitter is a polarization beam splitter.

6. The apparatus according to Claim 2, wherein each polarization rectifier includes a stack of said optical retarders which align the polarizations of all the color components.

7. The apparatus according to Claim 6, wherein the color components are red, green and blue and the polarization of the green component is orthogonal to the polarizations of the red and the blue components, and wherein each polarization rectifier includes: a stack of said optical retarders which rotate the green color component polarization direction by 90° leaving the polarizations of the other color components intact; and a polarization transformer.

8. The apparatus according to Claim 1, wherein said stacking means stacks the images outputted from said optical filter system by image warping onto said polarization preserving screen.

9. The apparatus according to Claim 1, wherein each of said projectors is an LCD projector outputting red and blue color components in one polarization state, and green color components in an orthogonal polarization state.

10. Stereoscopic display apparatus comprising:

two projection engines having inputs connectable to a source of digital data representing the color components sets of two stereoscopic images, each of said projection engines having an output outputting an optical beam having a set of color components in which at least one color component of the set is of an orthogonal polarization state with respect to the other color components of the set;

a polarization preserving screen;

a polarization rectifier for each projection engine effective to manipulate said polarization states exclusively by optical retarders, and to transform the beams outputted by the projection engines to beams in which all color components have the same polarization state in such a manner that the two transformed beams have mutually orthogonal polarizations;

a polarization beam splitter for combining the transformed beams into one co-axial beam;

and a projection lens for imaging the stereoscopic images on said screen.

11. The apparatus according to Claim 10, wherein each polarization rectifier includes: a splitter which separates the color components into two optical paths, a polarization transformer in at least one optical path which utilizes a said optical retarder to transform the respective color component to another polarization state in such manner that mutually orthogonal polarization states are transformed to polarization states that are also mutually orthogonal; and a combiner which combines the two optical paths for stacking onto said polarization preserving screen.

12. The apparatus according to Claim 11, wherein said splitter is a dichroic mirror.

13. The apparatus according to Claim 11, wherein said splitter is a polarization beam splitter.

14. The apparatus according to Claim 10, wherein each polarization rectifier includes a stack of said optical retarders which align the polarizations of all the color components in desired directions.

15. The apparatus according to Claim 14, wherein the color components are red, green and blue and the polarization of the green component is orthogonal to the polarizations of the red and the blue components, and wherein each polarization rectifier includes: a stack of said optical retarders which rotate the green color component polarization direction by 90° leaving the polarizations of the other color components intact; and a polarization transformer.